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TECHNICAL REPORT NO. 9890 (LL 117)

DESIGN AND FABRICATION
MOBILITY EXERCISE "A" TEST RIGS

December 1967

U.S. ARMY TANK-AUTOMOTIVE COMMAND LABORATORIES

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by

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DESIGN AND FABRICATION

MOBILITY EXERCISE "A" TEST RIGS

By

Paul L. Spanski

December 1967

AMCMS CODE: 5022.11.82200   PROJECT NO.: 1-V-0-21701-A-045

ABSTRACT

The purpose of this project was the design and construction of three mobility test rigs as postulated by the Vicksburg Mobility Exercise "A" document, dated February 1965. The construction of these test rigs was undertaken to generate the hardware necessary to prove the theory, advanced in the Exercise "A" document, that vehicles can be built to operate in a specified environment using existing techniques in mobility science. Covered in this report is an account of the design, construction, and initial testing of the three machines.

The characteristics of the three machines as delivered are summarized briefly below.

TEST RIG	WHEEL OR TRACTOR ARRANGEMENT	CONFIGURATION	UNIQUE FEATURES	GROSS CURB WEIGHT	CARGO CAPACITY
1	8x8	3-unit articulated steering.	Inching & pitch control between each unit.	12,500	5,000
2	10x10	2-unit articulated steering.	Inching & pitch control between each unit.	12,400	5,000
3	Tracks	2-unit articulated steering.	Inching & pitch control between each unit.	14,200	5,000

The completed hardware met all specifications as set forth in the Mobility Exercise "A" document, with the exception of the weight requirement. All three machines were overweight by 25 to 40% despite extensive use of aluminum throughout chassis and suspension.

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INTRODUCTION

Three test rigs were delivered in January and February of 1967. Initial operation of the machines was begun at the USATACOM Field Station near Houghton, Michigan. They were successfully demonstrated, tested briefly, and shipped to the Waterways Experiment Station, Vicksburg, Mississippi to undergo comprehensive field evaluation. Results of the brief test and demonstration were encouraging. The tracked test rig maneuvered well in deep snow and the two wheeled machines were able to negotiate deep snow without severe difficulties. Vertical steps of 36 inches were climbed and ditches up to 12 feet wide were crossed. The three test rigs generated approximately equal drawbar pull in deep snow. The drawbar pull readings ranged from 7,200 to 8,000 pounds.

OBJECTIVE

The objective of this project was the design and construction of three mobility test rigs for field evaluation to confirm the validity of the arguments presented in the Vicksburg Mobility Exercise "A" document.

CONCLUSIONS

As a result of testing and demonstration, the following conclusions were reached:

a. The 10x10 machine appears to be the most practical of the three. It performed as well as the 8x8 or the tracked machine, with the exception of the tracked machine's performance in snow, and yet is less complex than either of the other two.

b. The pitch control feature at the articulated joints proved very useful and was principally responsible for the excellent showing of the test rigs in comparison to the more conventional vehicles.

c. A roll lock is necessary on all three test rigs when bridging or obstacle negotiation is in progress.

d. The "inching" ability now appears much less useful than originally thought, based on performance in snow.

DESIGN PHILOSOPHY

Three Mobility Test Rigs are the hardware product of the Vicksburg Mobility Exercise "A" document, dated February 1965. Exercise "A" presents a new philosophy in cross-country vehicle design. It proposed, among other things, that the following criteria were important and must be followed in designing a successful vehicle for cross-country operation:

a. It is impractical and may be impossible to design a vehicle to excell in crossing all types of terrain and associated environment.

b. The practicality of a vehicle as a load carrying device or combat machine is inversly proportional in its attempt at being a "universal" vehicle.

c. It is concluded from statement b that a vehicle should be designed to operate in a relatively limited range of environments and that there would thus be a certain minimum number of practical vehicles which would cover all environments.

d. If a vehicle is to be designed for successful cross-country operation, the required elements for mobility must be the primary consideration. This statement is in sharp contrast to the philosophy followed in most previous vehicle design projects.

e. Vehicles of predictable cross-country performance can be designed from information presently available.

The last criterion is perhaps the most significant and is the basis for the design and construction of the three mobility test rigs. The test rigs were conceived at the Exercise "A" Conference. Using existing information from mobility research and environmental data, the three machines were designed to operate in a specific range of environments.

Taking into account the U. S. involvement in Southeast Asia, with its considerable areas of weak to very weak soils, it was decided to make these machines basically soft soil machines. However, it was also decided not to totally sacrifice other capabilities.

After much research of environmental data, it was decided to base the design on a soft soil with a one-pass strength of RCI 10,

or a 50 pass strength of RCI 25 with maneuvering respectively on the same soil strength. Other vehicle design parameters were drawn from good existing vehicle design practice. This included such features as steering by articulation and multi-unit construction. Some additional unique features were incorporated in the concept, such as "inching" ability in each articulated joint. In model tests, the ability to expand and contract the wheelbase of a vehicle has proven desirable as a soft soil mobility aid. An articulated vehicle, stuck in a localized mudhole, utilizes inching to extricate itself in the following manner. Starting in the contracted or minimum length position, the operator brakes the rear unit and applies power to the front unit. At the same time, power is also applied to the inching cylinder between units. Thus, the first unit develops its normal tractive effort, plus getting a push from the rear unit. This enables the first unit to move forward under conditions in which it would normally be immobilized. The functions of the two units are then reversed and the second unit is drawn up behind the first. The vehicle has thus moved ahead a few feet in "impassable" terrain.

Another unique feature was the inclusion of pitch control at each articulated joint. Normally the pitch control would be relaxed and the units of the vehicle allowed to assume any pitch attitude the terrain dictated. However, the operator has the option of locking the pitch attitude and thus making a rigid vehicle, or positively controling pitch attitude. These two modes of control were expected to assist in ditch crossing and obstacle negotiation ability, respectively.

After settling on these design features, the three test rigs took the following form:

a. A three-unit, 8x8, wheeled machine, 48x31.00 tire size.

b. A two-unit, 10x10, wheeled machine, 44x41.00 tire size.

c. A two-unit, tracked machine, 2 psi, Nominal Unit Ground Pressure (NUGP).

Artists concepts of the proposed machines and envelope drawings are shown in Plate Nos. 17, 18, 19, 20, 21 and 22, Mobility Exercise "A" document, and are reproduced in the Appendix of this report.

The three-unit machine was aimed at maximizing the ability to conform to large scale ground roughness. The 10x10 and tracked machine were proposed to be as nearly identical as possible both physically and in their predicted soft soil performance. The purpose of this was to establish absolute differences between the performance of wheels and tracks. All three machines were predicted to have approximately equal soft soil performance.

The report on Mobility Exercise "A" is dated February 1965. Coincident with the publication of the report, the Land Locomotion Division of the Mobility Systems Laboratory, USATACOM, was assigned the task of turning the three mobility test rig concepts into operating hardware.

The first step in this direction was a formal description of the characteristics desired. This was drawn up using the material presented in the Exercise "A" report. A copy of the physical and dynamic requirements as they finally appeared in the request for proposal and in the contract appears in the Appendix.

In studying these requirements it can be observed that the test rigs were designed to operate in a range of environments rather than simply in a range of soil strengths. The effects of the whole environment, other than soil strength, on mobility has received more and more attention in the past few years. In our opinion, soft soils represent only about 20% of the mobility problem. The specifications for the test rigs recognize this new attitude.

The proposed test program also recognizes this in that the primary tests are in soft soil but the supplementary tests propose ride studies, obstacle performance, slope performance, and traction on slippery surfaces.

DESIGN AND CONSTRUCTION

The purchase of the three machines was funded by AMC. The negotiation for the purchase was handled by ATAC Procurement by means of the two-step bidding process. Step I, Request for Technical Proposal, was dated 12 April 1965. The technical proposals were received in May. The technical evaluations were completed and Step II, money bid, was completed in August 1965. However, the contracting officer felt that all bidders were high and a re-bid was conducted. The re-bidding occurred in October 1965. The contract was then awarded to the Clark Equipment Company and the G. L. Bowen Company.

In November 1965 a meeting was held at the office of the G. L. Bowen Company. Personnel from G. L. Bowen, Clark Equipment Company and ATAC attended. It was a program review meeting prior to the detail design of the three machines. Several minor details were settled and the design work begun in earnest.

As shown in the Appendix, a schedule was set up by the Clark Equipment Company indicating the beginning and completion of the major activities in the design, fabrication, and build-up of the test rigs. As design activities progressed at Bowen, visits were made by ATAC personnel at approximately two-week intervals.

In order to minimize design time and fabrication expense, standard Clark Equipment drive-line parts were used wherever possible.

On the tracked machine it was decided to use the M116 track and suspension complete. It is an excellent example of the current state-of-the-art in band tracks and light vehicle suspensions.

A passive air spring suspension was introduced in the 8x8 and 10x10 versions. The purpose was to increase rough terrain crossing ability (improve ride) and to prevent the characteristic loping ride common to terra tire equipped machines.

During the engineering and design period only two significant engineering problems came up. One concerned individual axle roll capability relative to the chassis on the wheeled machines and the second concerned predicted overweight on all three test rigs.

G. L. Bowen personnel assumed that it was unnecessary to provide axle roll freedom due to the large deflection in the tires and the roll freedom between the units of a given machine. They felt wheel loadings would not be significantly affected. However, Land Locomotion Division personnel felt there would be significant variation in wheel loading especially in the two-unit 10x10 test rig. As a result, a roll capability was incorporated up to a maximum of 6° in each axle.

The second problem arose early in the design stages when a preliminary weight analysis showed that all three machines would be 50-70% over the design requirements. This was considered unacceptable. All areas of the design were re-examined and the following changes were made to reduce the weight:

a. Extensive use of aluminum in the chassis including the main frame, cargo deck, and axle control arms.

b. Switch to a lighter, smaller, power plant.

c. All cabs would be fabricated in aluminum by the contractor rather than using a purchased assembly.

d. Buffed tread on the terra tires for the 8x8.

e. One size reduction of tire size on the 10x10 (from 44x41.00 to 42x40.00).

f. Aluminum drop boxes.

g. Aluminum wheel rims.

The new target weights were as follows:

a. 8x8 test rig, 11,500 pounds.

b. 10x10 test rig, 11,500 pounds.

c. Tracked test rig, 13,500 pounds.

The target weights were still above the design weights of 10,000 pounds for each machine but were felt to be realistic in light of the current state-of-the-art of truck engineering.

Other than the preceding, the design, fabrication, and assembly proceeded with little technical difficulty. However, the assembly schedule slipped considerably. The contractor complained of slow vendor deliveries of custom sub-assemblies. Periodic trips were made by ATAC representatives to the Clark Equipment Development Division to view progress on the machines.

The delivery schedule originally called for the 8x8 to be delivered at the end of October, the 10x10 in November, and the tracked machine in December. As the time for the delivery of the first machine drew near it was evident that the schedule could not be met. The inching cylinders and the complex hydraulic systems were responsible for the delay.

The 10x10 was actually the first test rig to be delivered to Houghton, Michigan on 25 January 1967, the 8x8 and tracked machines

arrived on 9 February 1967. All machines arrived in running condition and were driven off the railroad flat cars to the Keweenaw Field Station. Delivery was made to the Field Station rather than directly to Vicksburg so that the machines could be demonstrated for USATACOM personnel. Also, a short test program was planned to shake the test rigs down while they were still relatively close to the contractor's plant. The three test rigs are shown in Figures 1, 2, and 3.

TESTING

Preliminary operation of the test rigs for familiarization was done under the guidance of Clark Equipment Company personnel. All controls were power assisted and thus the machines were physically easy to drive. However, because of the unusual capabilities of the machines, in particular the 8x8, the controls were comples. Effective usuage of the machine and its capabilities requires more than average training. With the exception of the 8x8, the test rigs can be described as extremely noisy in the operator's cab but quiet outside. The hydraulic pumps are responsible for most of the noise. Also, the cabs are totally lacking in sound insulation. The 8x8 was very quiet inside because the engine and hydraulic pumps are at the opposite end of the machine from the operator.

The transmission, transfer case, and winch controls operated erratically. Static, positive displacement, hydraulic linkages, are used to control these components. However, since the volume of a given amount of fluid varies with temperature, the controls were temperature sensitive. The controls were claimed to be compensated for this characteristic of the fluid but they still went out of adjustment readily to the point where it was impossible to shift the transmission or transfer case.

Although the wheeled test rigs were equipped with suspensions (passive air springs) they were not evaluated for ride or the elimination of loping at this time. As stated in the technical requirements of the contract, one of the functions of the suspension was the elimination of vehicle "loping" brought on by the low spring rate of the terra tires. This evaluation will be made later as part of the regular test program. The only experience with the hard surface ride at this time was that experienced during the delivery of the test rigs from the railroad siding to the Field Station, a distance of seven miles. At that time the air springs were flat and the tires were over-inflated. Under these adverse conditions a loping motion developed at a speed of 17 mph. Above (up to 23 mph) and below that speed the ride was smooth.

The unladen curb weight of the test rigs as shipped to Houghton was as follows:

a. 10x10 - 12,400 pounds.

b. 8x8 - 12,500 pounds.

c. Tracked machine - 14,200 pounds.

Between the arrival of the 8x8, the tracked test rig, and the public demonstration, a drawbar-pull test was conducted in snow. The primary purpose of the test was not to evaluate the test rigs in snow but to subject all vehicle components to severe operating conditions as part of the shake-down procedure. The three test rigs were operated in tough, compacted snow and produced very similar drawbar-pulls of 7,200 to 8,000 pounds each, see Figure 4. This preliminary test also showed we were successful in designing three different vehicles having the same soft-soil performance.

Starting on Monday, 20 February 1967 and extending through the week, several mobility experts were invited to Houghton for a semi-formal presentation and demonstration of the operation of the three mobility test rigs. Those invited included personnel from ATAC as well as interested parties from private industry and other Government installations. The program started with a verbal presentation and then moved into the field to observe the test rigs in action. The schedule of events included the following:

a. Ditch crossing (6, 8, 10, and 12 ft. width).

b. Vertical step climbing (18, 24, 30, and 36 in. high).

c. Hill climbing (15 ft. x 15%; 15 ft. x 30%).

d. Maneuvering in snow.

In order to provide a basis for comparison, several familiar snow and soft-soil vehicles were run in competition. Included were the following:

a. Nodwell 110.

b. M29C Weasel.

c. Thiokol Spryte.

d. Thiokol Imp.

e. POLECAT

f. Tucker Sno-Cat

Photographs of some of these machines running in the demonstration appear in Figures 5, 6, and 7. Each Mobility Exercise "A" test rig carried its rated load of 5,000 pounds. The comparison vehicles ran unloaded.

The most significant difference between the test rigs and the comparison vehicles was in the ditch crossing and vertical step negotiation. All the mobility test rigs were an order of magnitude better than most of the comparison vehicles as shown by the performance summation chart and photographs (Table 1, Figures 8 through 16) in the Appendix. This remarkable performance by the test rigs was attributable entirely to the pitch control capability. In ditch crossing, the use of pitch lock enables the test rigs to act as rigid frame machines and thus bridge extremely wide trenches. The use of positive pitch control enabled the test rigs to lift the forward portion of the first unit off the ground so that the front wheels or tracks would actually be set down on top of the vertical step. In the case of the 8x8, the entire front unit was lifted off the ground.

On the 8x8 machine, an operational hazard became apparent because of the pitch control capability. The articulated joints in the 8x8 as well as in the other machines have total roll freedom. That is, any two units may rotate relative to one another around a longitudinal axis until stopped by some exterior restraint. As a result of this feature, when either the front or rear unit of the 8x8 are lifted off the ground they are unstable and have a tendency to roll. ~~Several near accidents~~ resulted from this situation.

Another operational quirk peculiar to the 8x8 was the difficulty in precise steering on low friction surfaces. Due to the very low wheel loading on the front unit of the 8x8, it was sometimes difficult to develop sufficient lateral forces during steering maneuvers. The front unit would simply be pushed sideways in the original direction of travel. This situation was soon found to be correctable by using the first joint pitch control to transfer some weight from the second unit to the first.

The operation of the three mobility test rigs in deep snow gave mixed results. It is generally accepted that wheeled vehicles are not good snow machines, so not much was expected of the 8x8 or 10x10 in

snow. The fact that they were able to maneuver at all in deep snow was impressive. Both inching and pitch control were evaluated as a deep snow mobility aid. The wheeled machines were able to maneuver in snow with sinkages of 18 to 24 inches. Using "inching" alone as a mobility aid was disappointing. There was a tendency for the wheels of the front unit to "dig in" faster than the unit could be pushed forward. Better results were obtained by using the pitch control to drastically alter wheel loadings. After a test rig became immobilized in snow, proceeding in a conventional manner, the following technique was used to regain headway. The front axle was lifted off the ground, thereby eliminating a major portion of the bulldozing resistance. The remaining wheels in contact with the ground then rode on compacted snow and experienced little motion resistance. The test rig proceeded forward in this manner until it became immobilized again by a build-up of snow in front of the wheels on the second axle. The pitch control was then used to load the first axle and lift the second axle. Forward motion was again possible due to reduced bulldozing. However, after a short distance, bulldozing resistance increased on the front axle and forward motion stopped. The cycle was then repeated by lifting the front axle and loading the second axle. Progress could continue indefinitely using this seesaw technique. This technique worked for either the 8x8 or the 10x10. However, the average speed was very low when compared to the tracked test rig or a good snow machine such as the Tucker Sno-Cat. During these tests, however, the tires on the test rigs were inflated to about 8 psi.

The tracked test rig negotiated deep snow without difficulty but experienced greater sinkage than the other tracked machines such as the POLECAT which is similar in configuration. The nominal unit ground pressure of the tracked test rig with load is about 2.5 psi versus 1.5 psi for the Weasel, and 2.1 psi for the POLECAT.

The hill climbing performance of the three test rigs also provided some unexpected results. Both the shallow and steep grades were negotiated without difficulty by the 8x8 and the 10x10 machines. The tracked machine experienced some difficulty on the steep grade. The problem was lack of traction on the hard packed dry snow. Again by using pitch control to change weight distribution the hill was successfully negotiated. The Nodwell 110 failed to climb the steep hill because it was power limited. The Spryte failed due to lack of traction, as did the Imp.

The impression gained of the three test rigs during these informal trials was one of great capability even when operating outside the environment for which they were designed. Contributing to

this impression was the low incident of vehicle failures which are normally common in an unusual design. Only one significant failure occurred. The lower pitch cylinder anchor on the tracked machine and the 10x10 failed during a trench crossing operation. The failure occurred along weld lines. The annealed aluminum weld had only about half the yield strength of the original heat-treated alloy. Minor malfunctions also occurred in the hydraulic systems but were usually corrected on the spot. The most annoying difficulty was the inability to keep the hydrostatic control linkages in adjustment.

Conclusions reached upon the completion of the preliminary testing:

a. The 10x10 machine appears to be the most practical of the three. It performed as well as the 8x8 or the tracked machine, with the exception of the tracked machine's performance in snow, and yet is less complex than either of the other two.

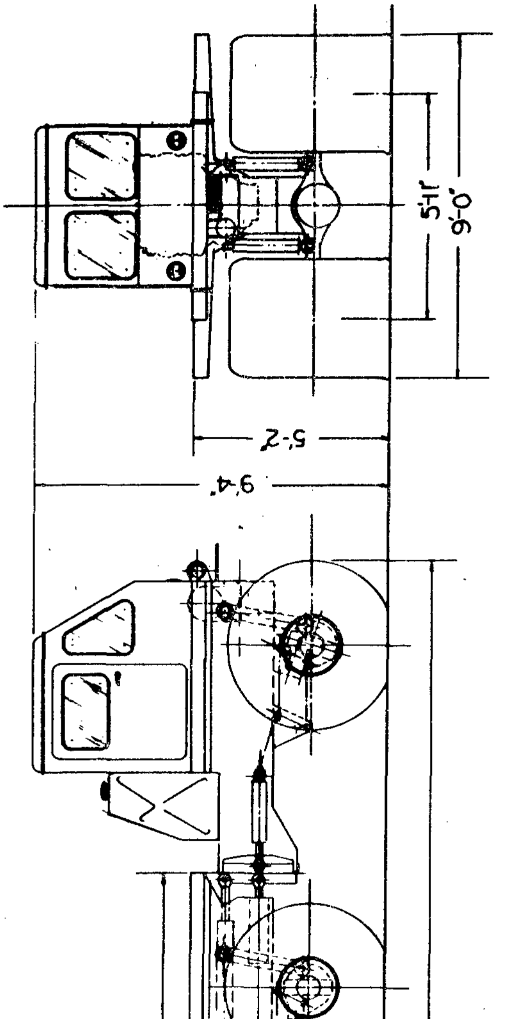
b. The pitch control feature at the articulated joints proved very useful and was principally responsible for the excellent showing of the test rigs in comparison to the more conventional vehicles.

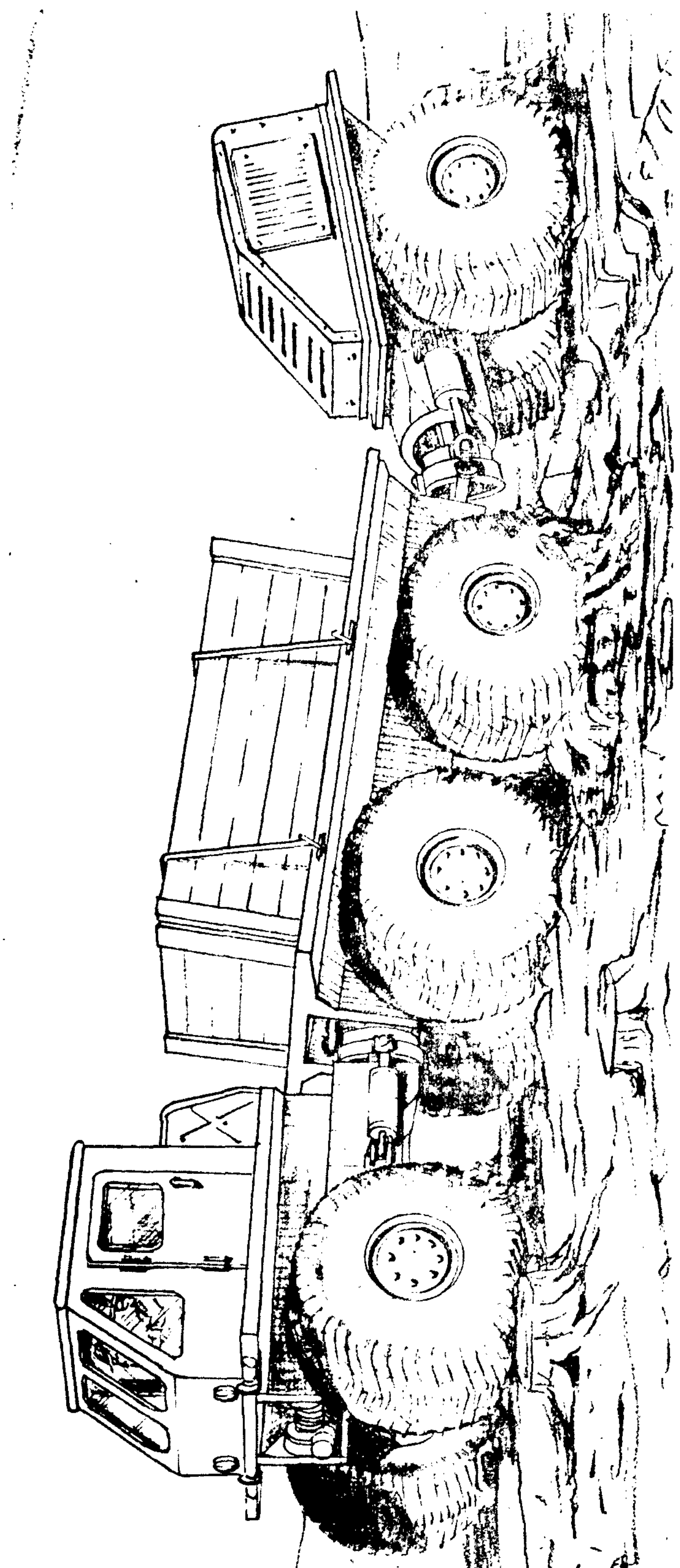
c. A roll lock is necessary on all three test rigs when bridging or obstacle negotiation is in progress.

d. The "inching" ability now appears much less useful than originally thought, based on performance in snow.

APPENDIX

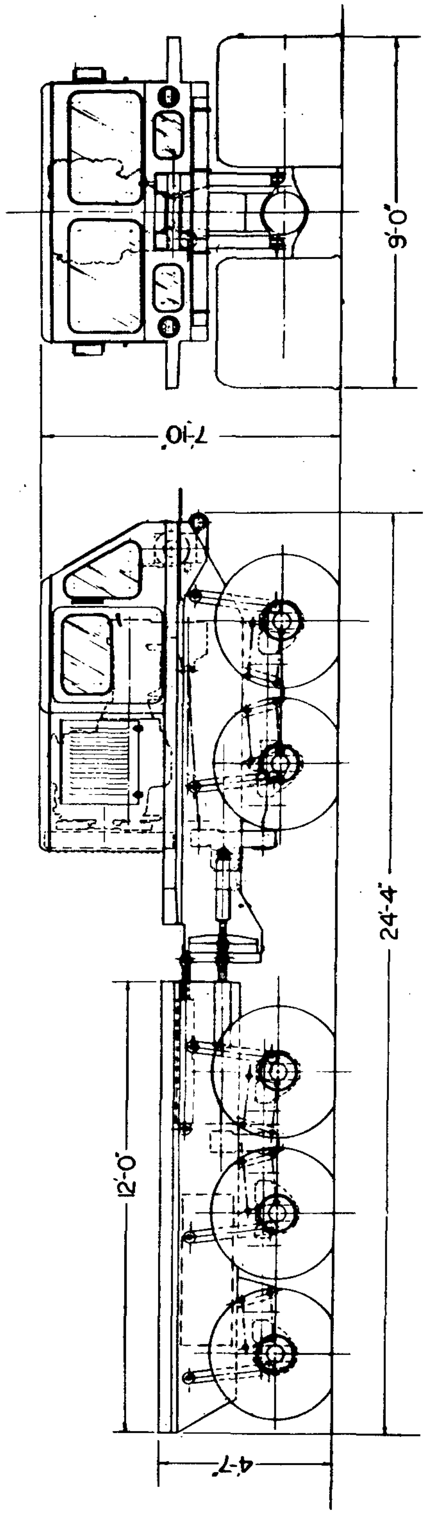
8 X 8 WHEELED CONCEPT





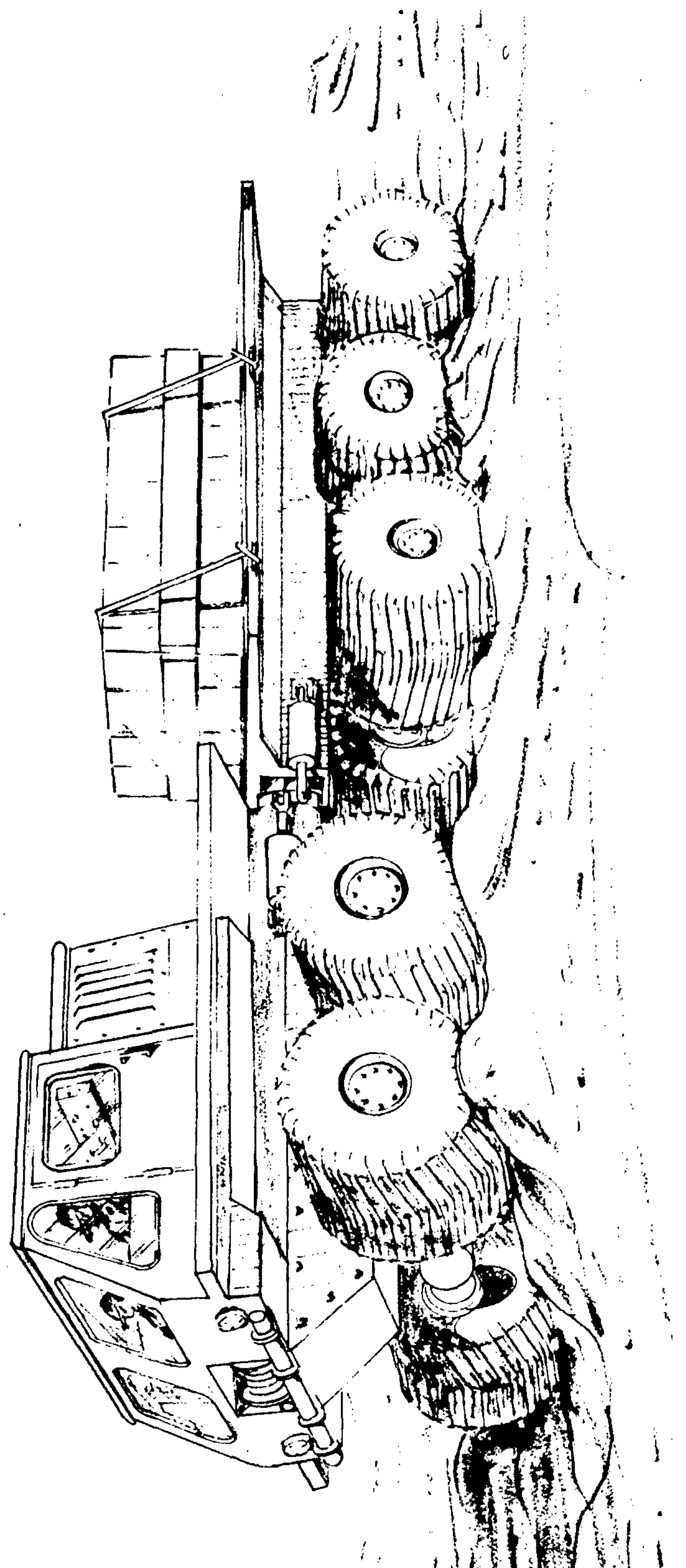
ARTIST CONCEPTION OF 8 X 8 WHEELED CONCEPT

PLATE 18



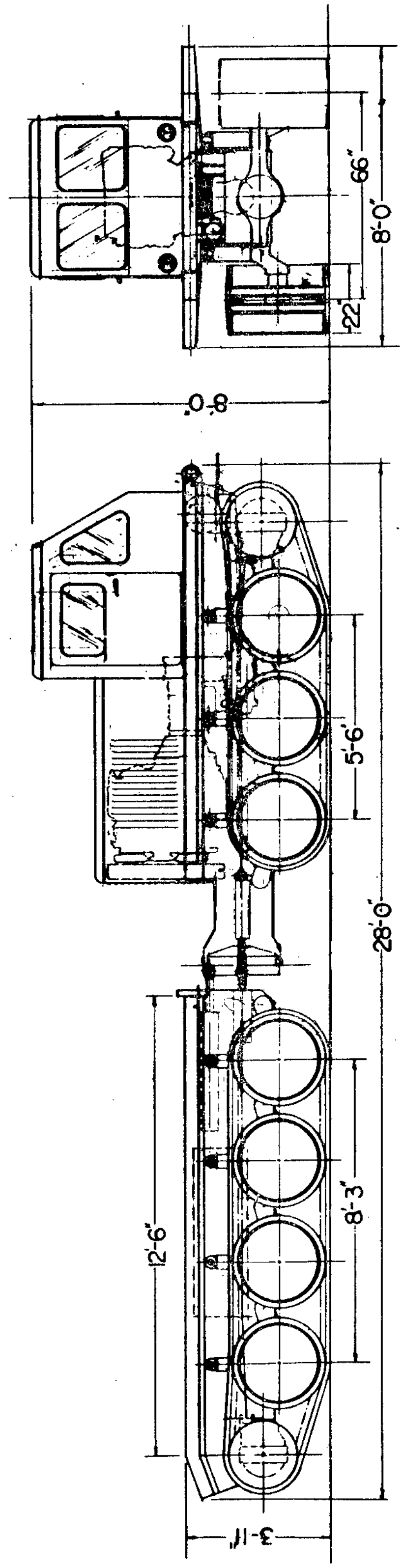
10 X 10 WHEELED CONCEPT

PLATE 19

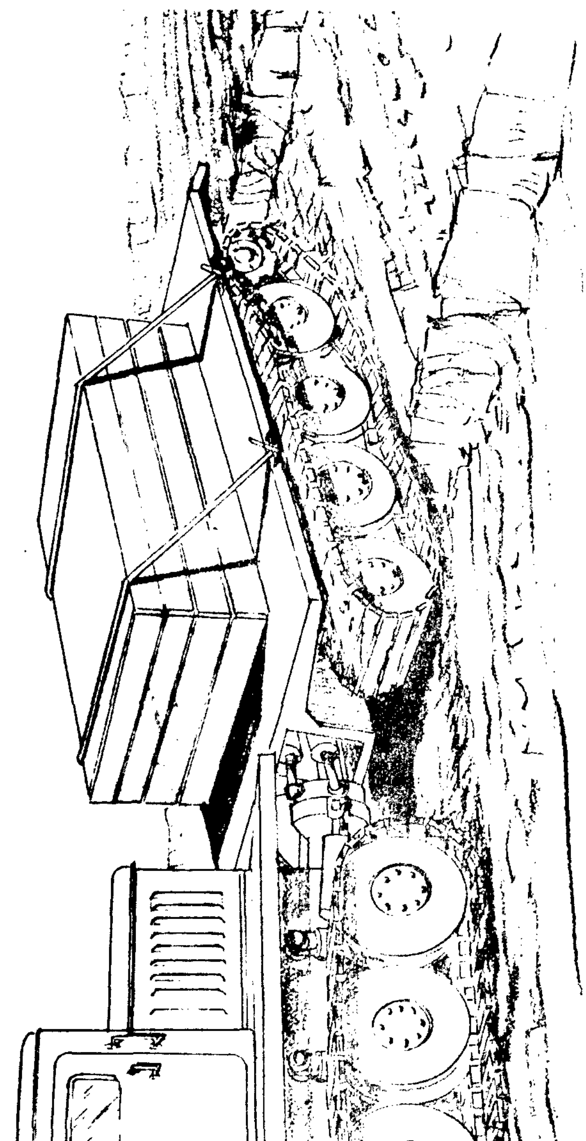


ARTIST CONCEPTION OF
10X10 WHEELED CONCEPT

PLATE 20



TRACKED CONCEPT



ARTIST CONCEPTION
OF TRACKED CONCEPT

PLATE 22

Extract - Contract No. DA-20-113-AMC-07865(T)

Physical and Dynamic Requirements

I. OBJECTIVE

To design and construct three (3) Mobility Test Rigs with the primary ability to operate in soft soils while retaining a secondary ability to qualify as load carrying vehicles.

II. AUTHORITY

Procurement Request No. 65-25, dated 8 March 1965.

III. DISCUSSION

The implementation of an extensive soft soil mobility test program requires the design and construction of three mobility test rigs. The primary consideration in the conception of these test rigs is the ability to operate in soft soils. They shall, however, retain sufficient practicality to qualify as load carrying vehicles.

IV. REQUIREMENTS

The test rigs will consist of the following three (3) configurations:

a. A wheeled 8x8, three-unit, articulated vehicle.

b. A wheeled 10x10, two-unit, articulated vehicle.

c. A tracked, two-unit, articulated vehicle.

Physical and Dynamic Requirements:

The three proposed test rig vehicles will encompass the following physical characteristics and dynamic capabilities:

a. General physical specifications (applicable to all three test rigs)

(1) Development of designs that demand a minimum of new and unproven techniques.

(2) Maximum gross vehicle weight of 15,00 pounds.

(3) A minimum of 15 hp/ton of gross vehicle weight.

(4) Height and width to conform to generally accepted dimensions for present U. S. Army 2-1/2 ton cargo carriers.

(5) Angles of approach and departure no less than 90°.

(6) Reduction of break angles to a minimum.

(7) Ability to transport 5,000 lbs. of cargo @100 lbs./ cu. ft. density in off-road operation.

(8) Each test rig shall have a winch with a minimum capacity of 10,000 lbs.

b. Special Physical Specifications, 8x8 concept:

(1) Three unit articulated vehicle incorporating "inching" ability between each unit. "Inching" is defined as the ability to have controlled linear relative motion between any two units of an articulated vehicle. The motion shall have a magnitude equal to approximately 1/6 the length of a single unit of the vehicle, but not less than two (2) feet. Control of the "inching" motion shall be exercised by the operator of the vehicle.

(2) Wheel Arrangement, 8x8. Two wheels on the first unit, four wheels on the second unit, and two wheels on the third unit. All wheels drive.

(3) Maximum overall length, 30 feet.

(4) The articulated joint shall have freedom in roll, pitch, and yaw.

(5) The articulated joint shall have pitch lock and pitch control. Pitch control shall be exercised from 30° above to 30° below the horizontal. (Pitch lock is defined as the ability to maintain a given angular relationship in the vertical plane between any two units of an articulated vehicle. Pitch control is defined as the ability to control the angular relationship in the vertical plane between any two units of an articulated vehicle).

(6) Tires shall be of "Terra Tire" or similar proportions to provide minimum vehicle silhouette.

c. Special Physical Specifications, 10x10 Concept:

(1) Two-unit articulated vehicle, incorporating "inching" ability between each unit.

(2) Wheel Arrangement, 10x10, four wheels on first unit, six wheels on the second unit.

(3) Maximum overall length, 26 feet.

(4) The articulated joint shall have freedom in roll, pitch, and yaw.

(5) The articulated joint shall have pitch lock and pitch control. Pitch control shall be exercised from 30° above to 30° below the horizontal.

(6) The tires shall be of "Terra Tire" or similar proportions to provide a minimum vehicle silhouette.

d. Special Physical Specifications - Tracked Concept:

(1) Two-unit articulated vehicle incorporating "inching" ability between each unit.

(2) Two tracks on each unit of sufficient area to produce a ground pressure no greater than 2 psi.

(3) Maximum overall length, 30 feet.

(4) The articulated joint shall have freedom in roll, pitch, and yaw.

(5) The articulated joint shall have pitch lock and pitch control. Pitch control shall be exercised from 30° above to 30° below the horizontal.

e. Dynamic Capabilities - All Test Rigs:

(1) Based on existing theory, the test rigs shall be capable of traveling on a soil having a strength of 25 RCI for 50 passes, and of 10 RCI for a single pass. The Land Locomotion Laboratory Soil Value System defines this soil in the following terms:

$$c \text{ (cohesion)} = .82 \text{ lb./in.}^2$$

$$k_c = 2.2 \text{ lb./in.}^{n+1}$$

$$k_o = 1. \text{ lb./in.}^{n+1}$$

$$k_b = 1 \text{ (dimensionless)}$$

$$k_\theta = 1 \text{ (dimensionless)}$$

$$n = .35 \text{ (dimensionless)}.$$

$$\gamma \text{(density)} = .06 \text{ lb./in.}^3$$

$$\phi \text{ angle of internal friction} = 19.7^\circ$$

This capability infers a ground clearance adequate to bellying prior to immobilization by inadequate traction.

(2) Based on existing off-road mobility thereof the test rigs shall be capable of 5 mph in the minimum soil strength.

(3) The test rigs shall have the ability to ford a 4 ft. deep stream.

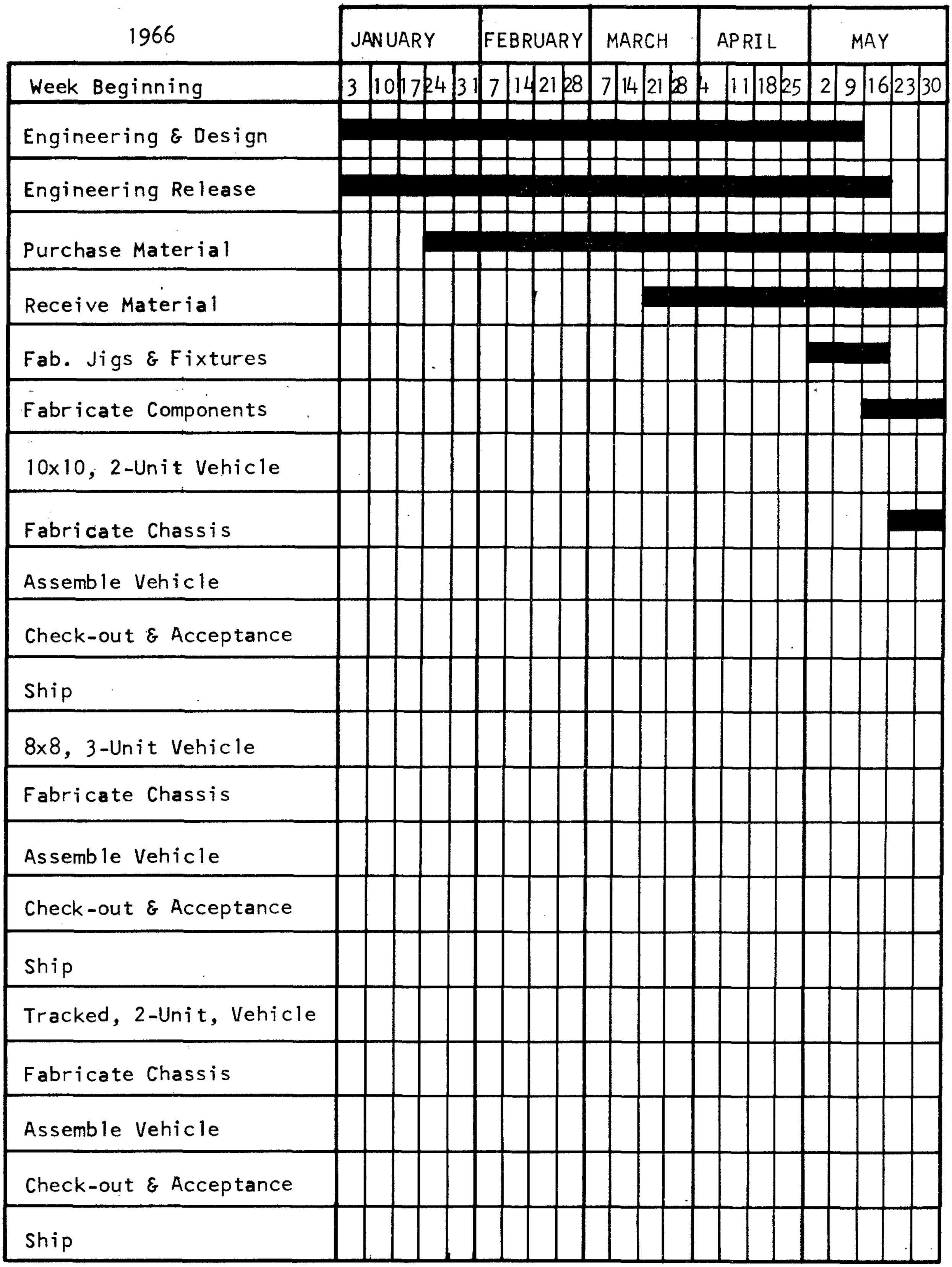
(4) The test rigs shall have the ability to negotiate a 3 ft. high obstacle.

(5) A suspension shall be provided on each test rig which will minimize or eliminate "loping" during high speed cross-country or highway operation.

(6) Each test rig shall have sufficient durability to operate for 500 hours without major component failures. The contractor will be responsible for furnishing spares, at no cost to the Government, of any major component which does fail in less than 500 hours of vehicle operation.

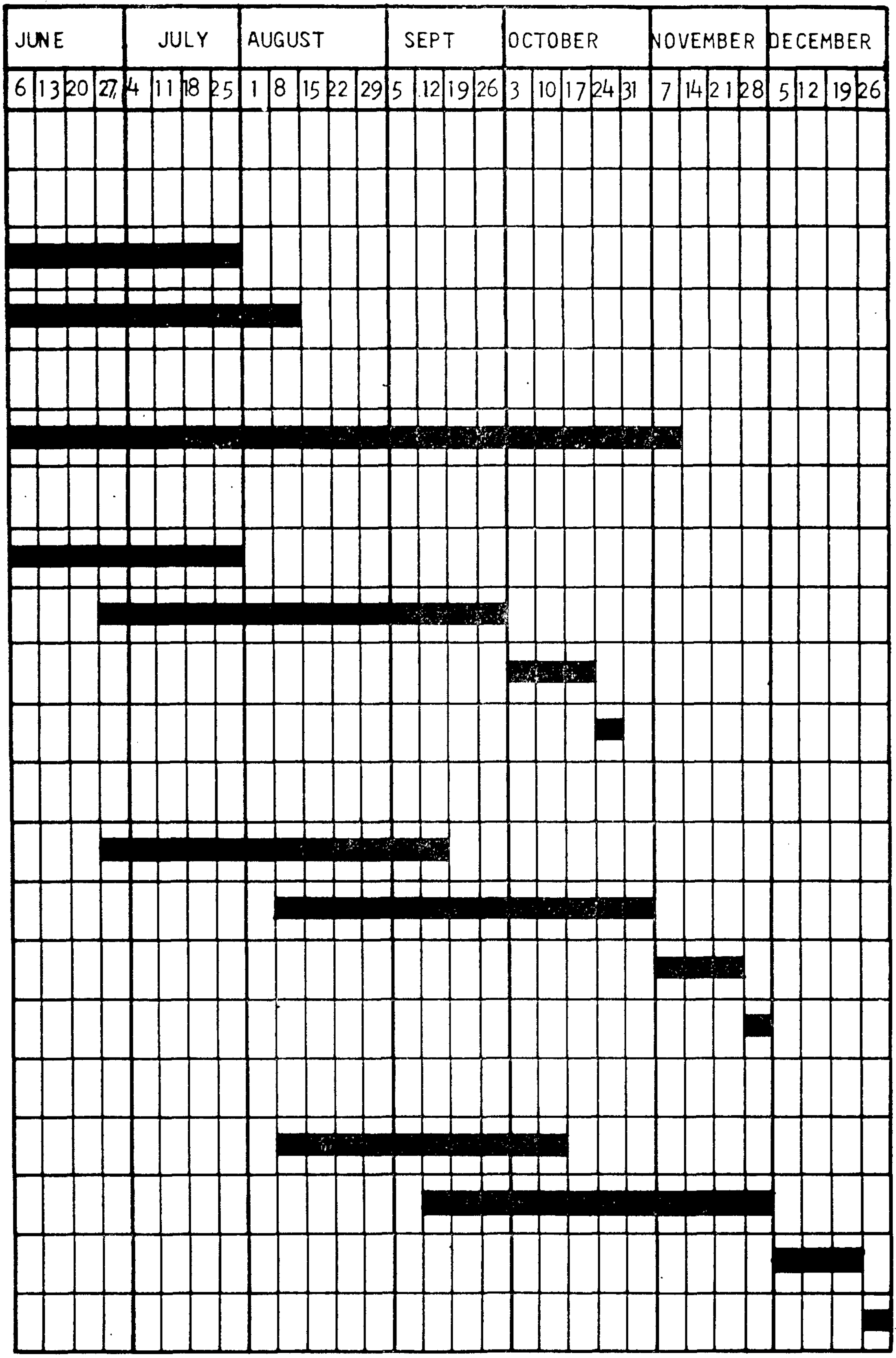
TIME SCHEDULE

Three Mobility Test Rigs



TIME SCHEDULE

Three Mobility Test Rigs



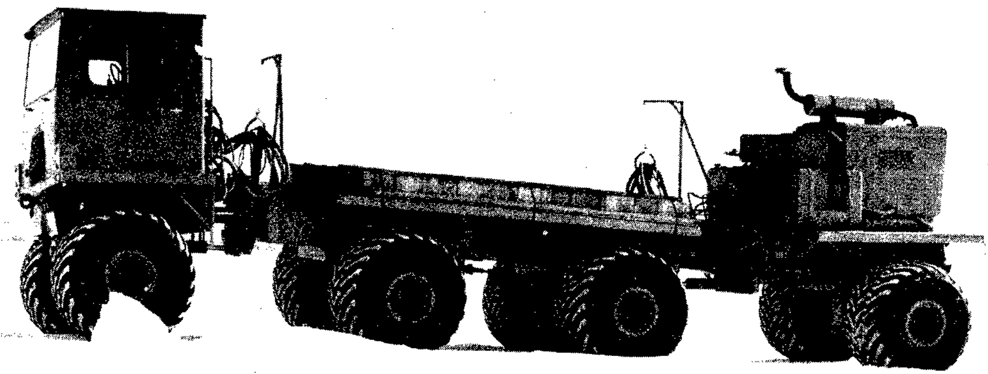


Figure 1: 8x8 Test Rig Approaching Trench Obstacle.

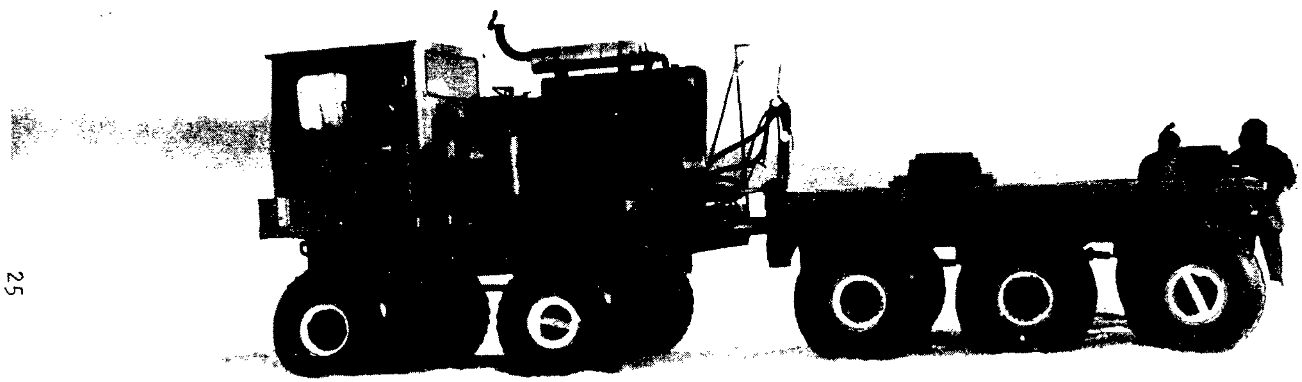


Figure 2: 10x10 Test Rig. Note the undercarriage contains the maximum number of wheels within the vehicle envelope.

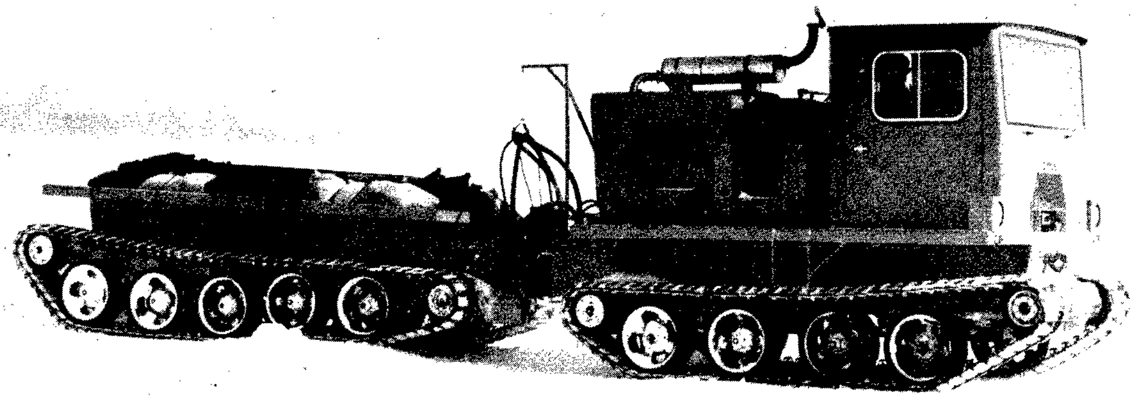


Figure 3: Tracked Test Rig. Note the M116 Track and Suspension components.

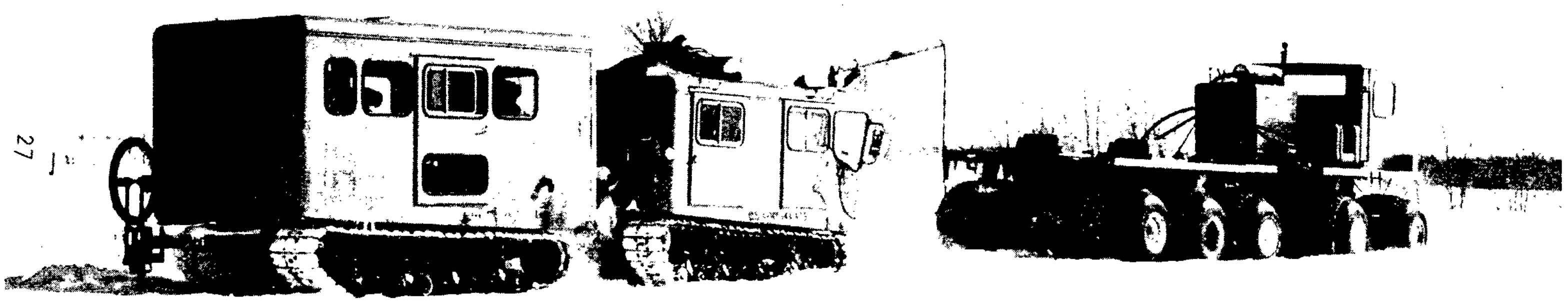


Figure 4: The 10x10 Test Rig is undergoing a Drawbar-Pull Test. The Dynamometer vehicle is a POLECAT.

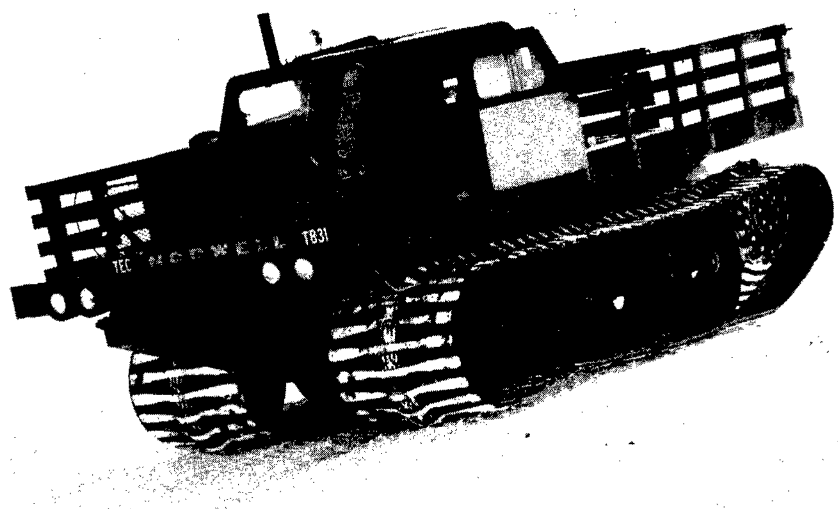


Figure 5: The Nodwell RN110, one of the comparison vehicles, coming over the crest of the hill climb obstacle.

Figure 6: The Tucker Sno-Cat, a highly specialized and effective snow traveling vehicle.

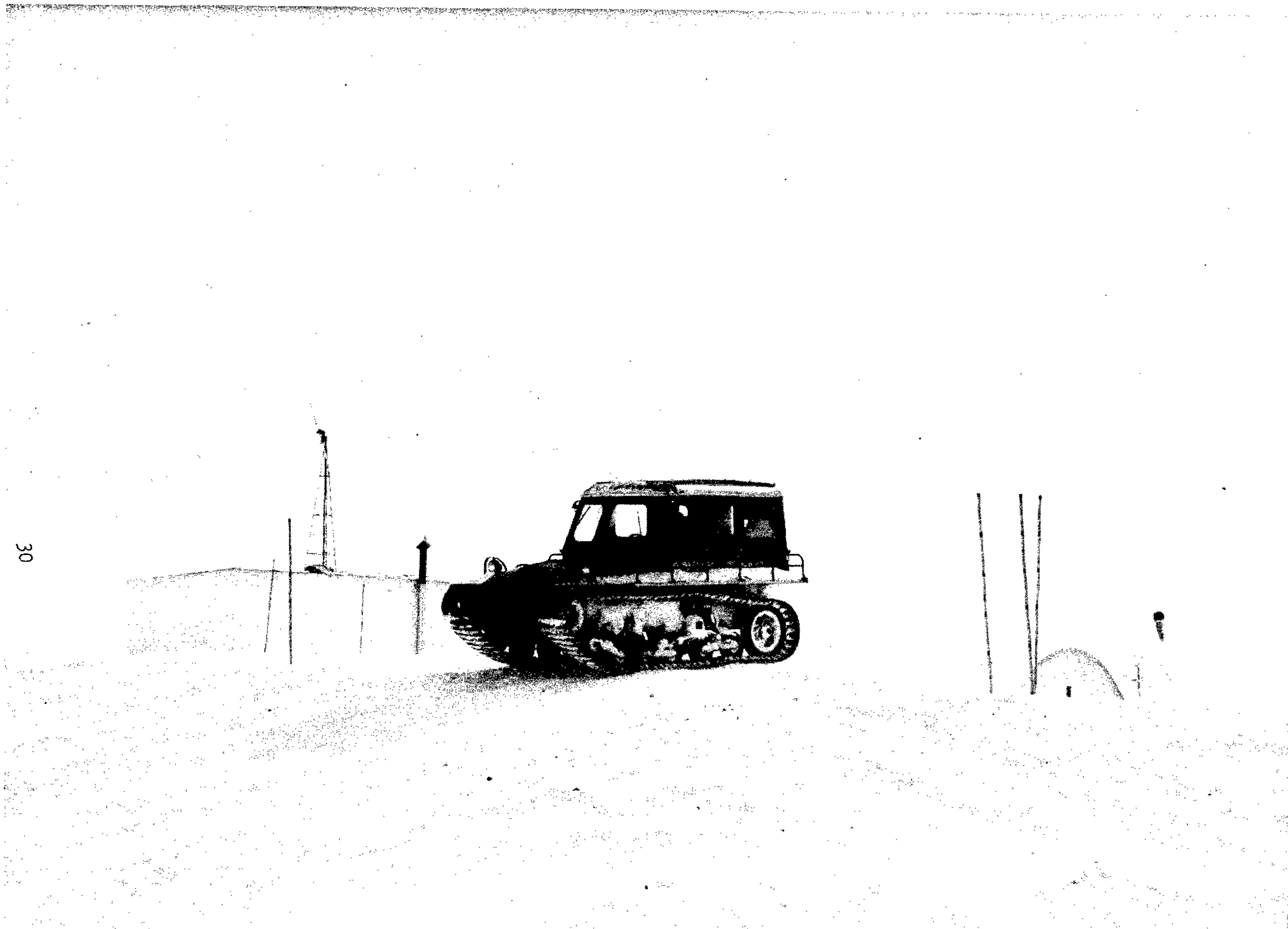


Figure 7: The Sno-Trac, a successful, low cost, tracked snow machine of Swedish manufacture using a VW Engine.

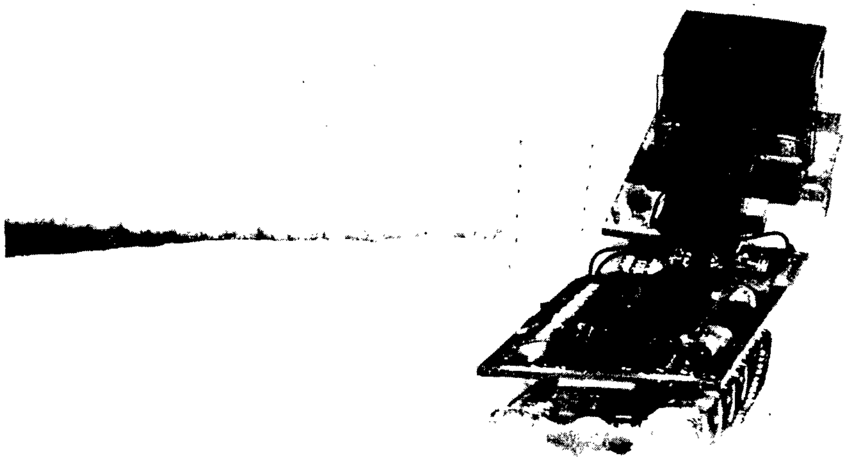


Figure 8: The Tracked Test Rig negotiating the 30% grade of snow.

Figure 9: The Nodwell RN 110 negotiating 24 inch vertical step.

Figure 10: The POLECAT Comparison Vehicle immobilized by the 36 inch vertical step.

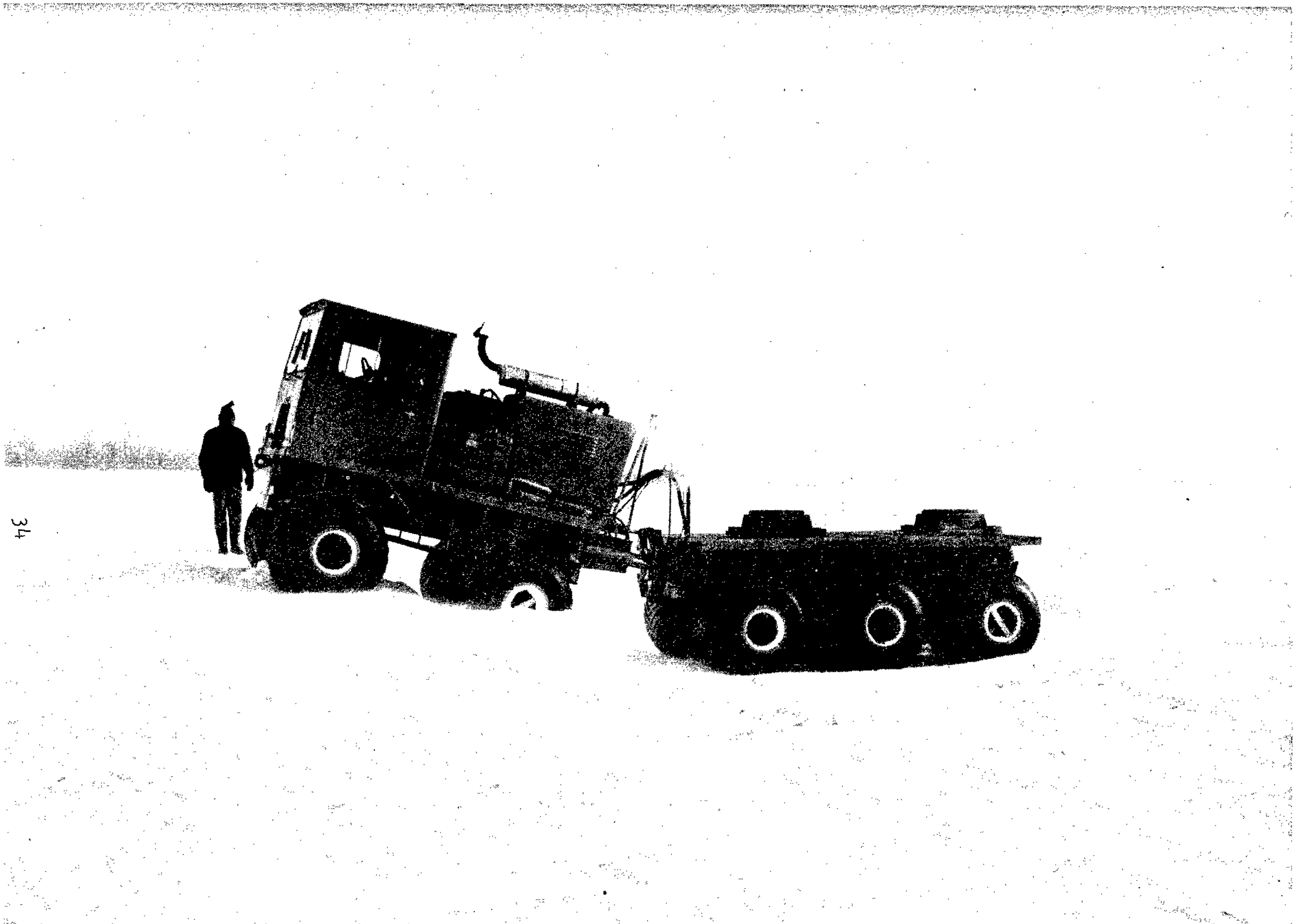


Figure 11: The 10x10 Test Rig climbing the 24 inch. vertical step.

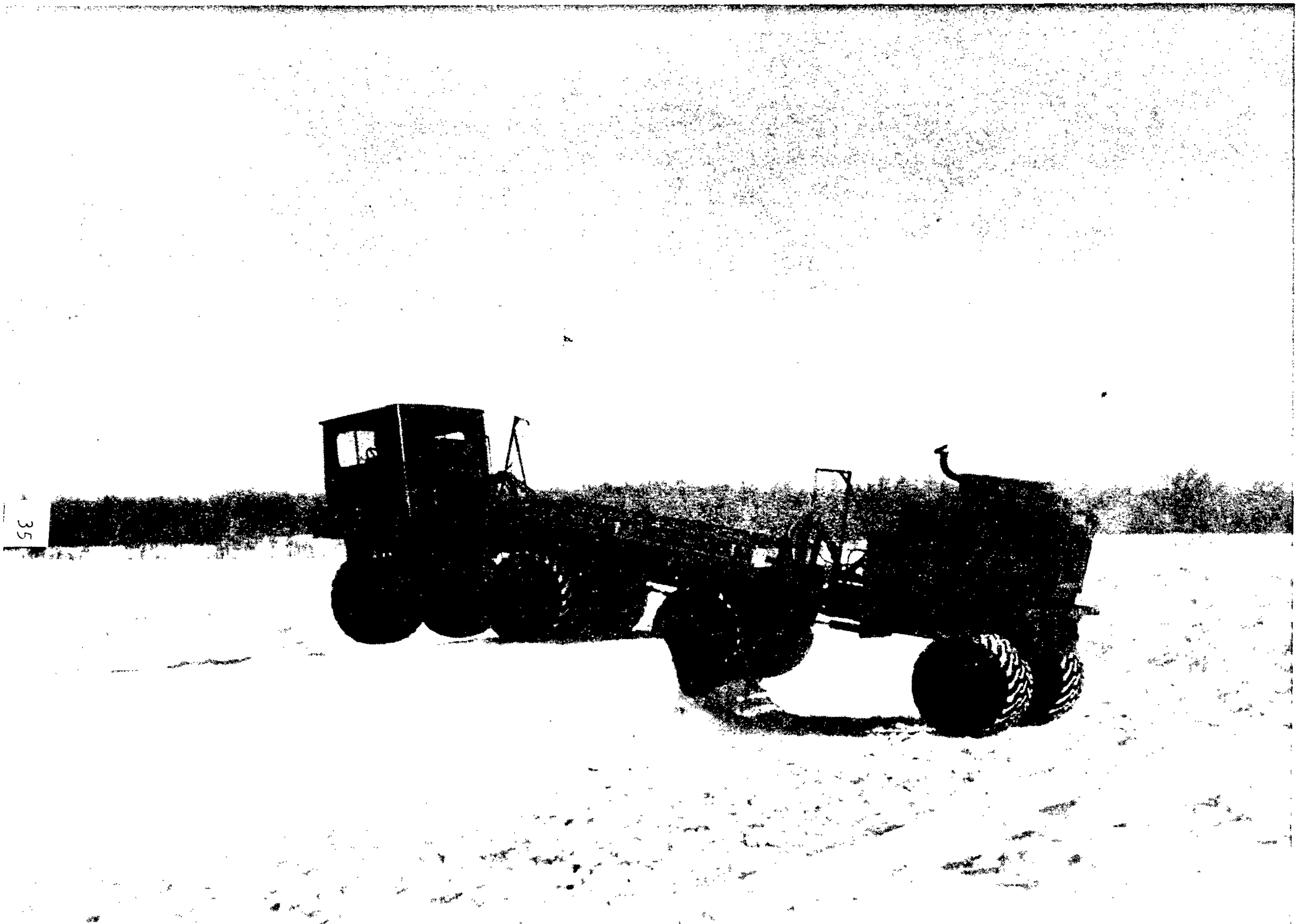


Figure 12: The 8x8 Test Rig climbing 36 inch vertical step.

Figure 13: The Tracked Test Rig climbing the 36 inch vertical step.

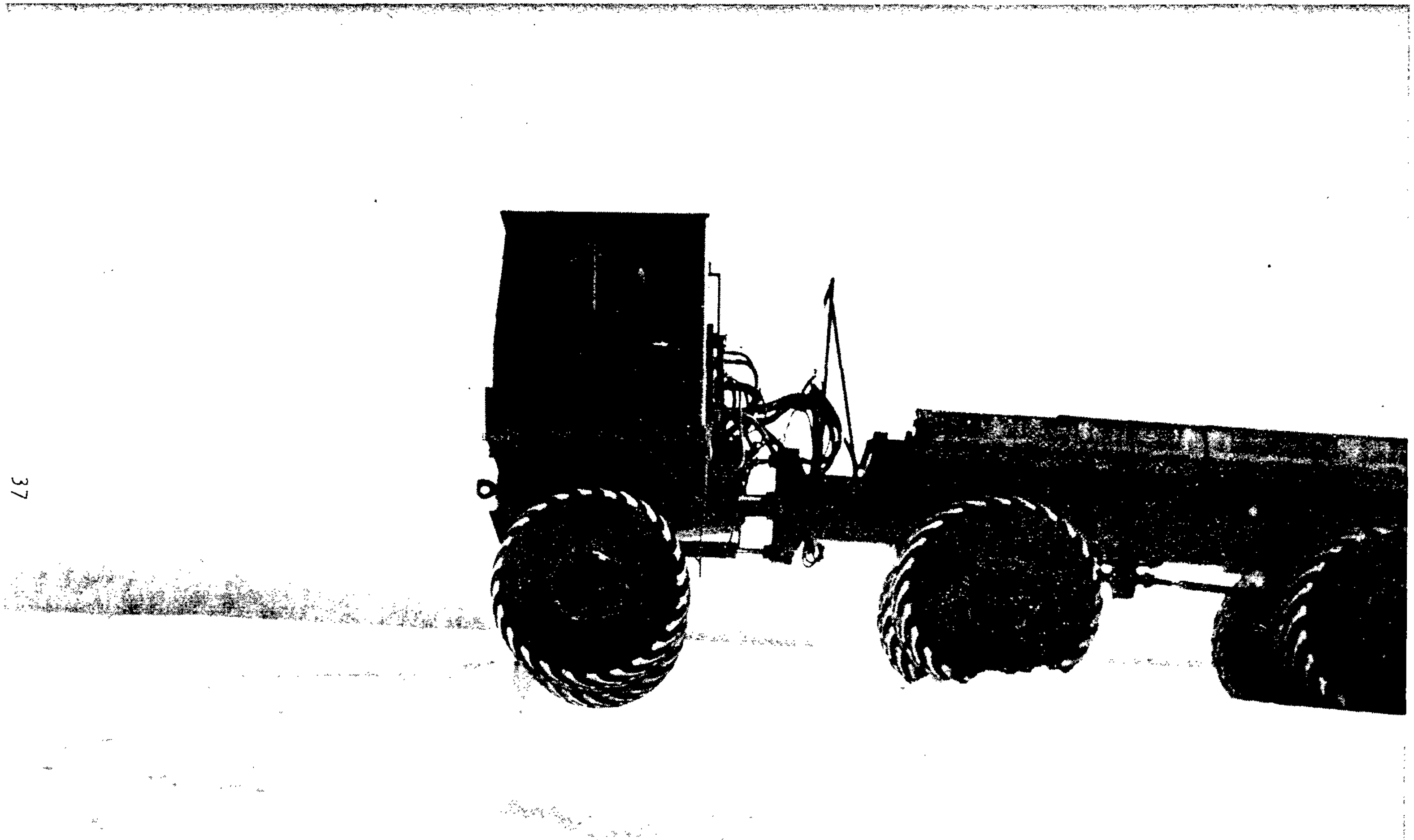


Figure 14: The 8x8 Test Rig bridging the 8 foot wide trench.

Figure 15: The 10x10 Test Rig bridging the 10 foot wide trench.

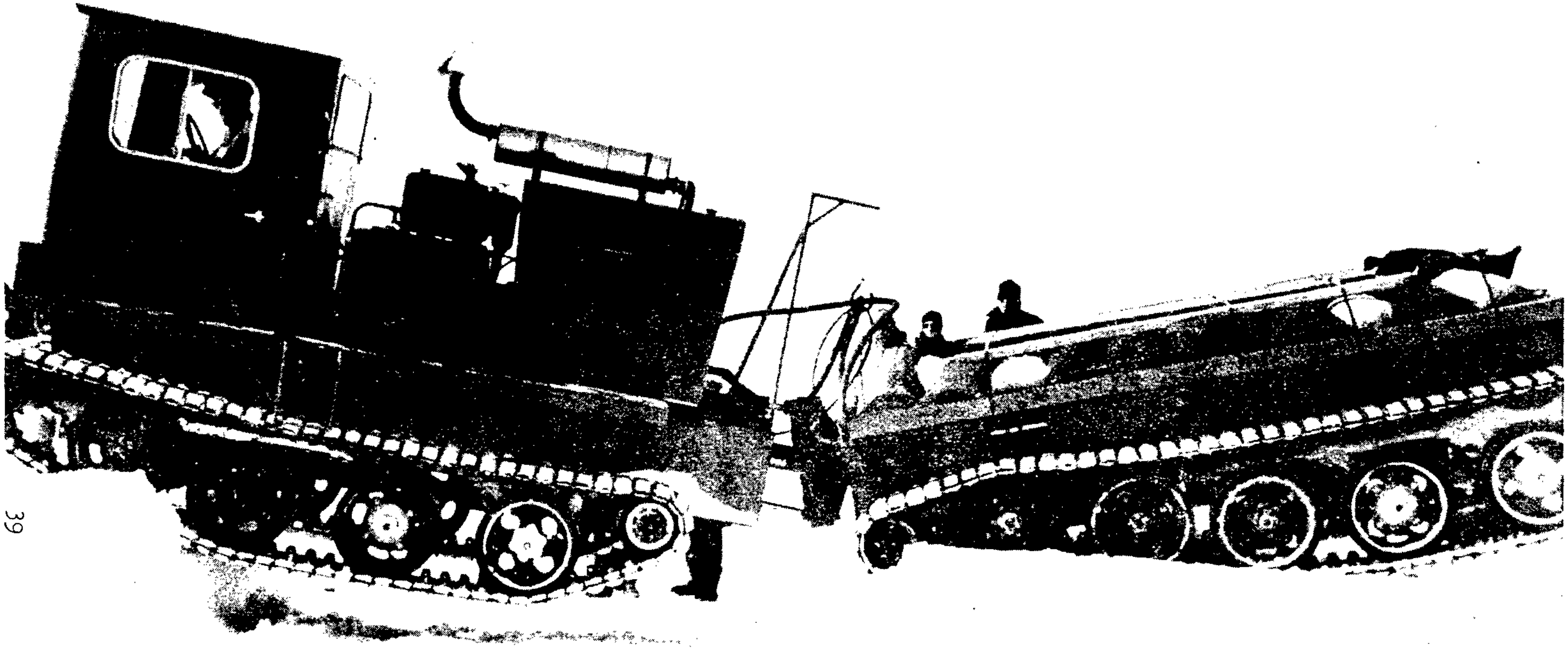


Figure 16: The Tracked Test Rig bridging the 12 foot wide trench. Mechanical failures of the hydraulic cylinder anchors prevented successful completion of the crossing.

PERFORMANCE SUMMATION

VICKSBURG MOBILITY EXERCISE "A" TEST RIGS

WINTER DEMONSTRATION, HOUGHTON, MICHIGAN

ACTIVITY	HILL CLIMB Compacted Snow GRADE		VERTICAL STEP (inches)				DITCH CROSSING (feet)				MANEUVERING IN SNOW		DRAWBAR-PULL IN COMPACTED SNOW		REMARKS
Vehicle	15%	30%	18	24	30	36	6	8	10	12	Compacted	Deep, Soft	Moving	Maximum	
Mobility Test Rig 3-Unit, 8x8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Good	Poor to Fair	4000	7200	Tires inflated to 8 psi
Mobility Test Rig 2-Unit, 10x10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Good	Poor to Fair	5000	7800	Tires inflated to 8 psi
Mobility Test Rig 2-Unit, Tracked	Yes	Yes*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good	Good	5000	8000	High sinkage in snow, 2.5 psi NUGP with 5,000 lb. load
Nodwell RN1100	Yes	No	Yes	Yes**	Yes**	Yes**	Yes	No	No	No	Good	Good	Not tested		
POLECAT	Yes	Yes	Yes	No	No	No	No	No	No	No	Good	Good	Not tested		
M29 Weasel	Yes	Yes	Yes	No	No	No	No	No	No	No	Good	Good	Not tested		
Tucker Sno-Cat	Yes	Yes	Yes	No	No	No	No	No	No	No	Good	Good	Not tested		
Thiokol Spryte	Yes	No	Yes	No	No	No	No	No	No	No	Good	Good	Not tested		
Sno-Trac	Yes	Yes	Yes	No	No	No	No	No	No	No	Good	Good	Not tested		
Thiokol Imp	Yes	No	No	No	No	No	No	No	No	No	Good	Good			

*Yes with difficulty. Required the use of pitch control to adjust weight distribution for better traction.

**The Nodwell battered down the top edge of the step considerably in the process of climbing, so that the step was not truly vertical.

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The purpose of this project was the design and construction of three mobility test rigs as postulated by the Vicksburg Mobility Exercise "A" document, dated February 1965. The construction of these test rigs was undertaken to generate the hardware necessary to prove the theory, advanced in the Exercise "A" document, that vehicles can be built to operate in a specified environment using existing techniques in mobility science. Covered in this report is an account of the design, construction, and initial testing of the three machines.

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